

FIXATED OPTOKINETIC NYSTAGMUS AS AN INDICATOR OF THE  
ROLE OF VISION IN MOVEMENTS

Yu. B. Gippenreyter and G. L. Pik

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16. Abstract  In the present study, an attempt was made to extend the investigation of FOKN (Fixation Optokinetic Nystagmus) to a new category of problems, hand movements. The purpose of this work was to elucidate whether FOKN responds to the extent of visual participation in motor acts.			
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# FIXATION OPTOKINETIC NYSTAGMUS AS AN INDICATOR OF THE ROLE OF VISION IN MOVEMENTS

Yu. B. Gippenreyter and G. L. Pik\*

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The problem of the role of vision in movements has several aspects. The first aspect is related to the existence of an "external ring" in the control of movements. An extensive category of movements is constructed and is initially accomplished under optic control, for example, many movements of the C level according to N. A. Bernshteyn. As such movements become automated, their control enters the "internal ring", which closes through muscular proprioception. Well-known examples of movements with a similar history are extension of the hand to a switch in the dark, or a signature which we can write without gazing at the hand. It is understandable that cases of pure movements which are only optically or proprioceptively afferent are fairly rare and the bulk of occupational-working movements, as well as those occurring in sports and in everyday life, etc., constitute intermediate cases. With regard to these movements, it is preferable to speak about the relative role or specific importance of the visual components in the general afferent flow which maintains the movement control.

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\*\* Numbers in margin indicate pagination in original foreign text.

Another aspect of the same problem is related to the utilization of visual images from the environment or of visual spatial representations in motor problems. For example, movements, which are intended to reproduce metric or spatial properties of an object which is known but absent in the given moment, are accomplished by visual representation. Thus, we can draw with a greater or lesser amount of success a 10 cm line by using a standard which is preserved in lasting memory. In / 70 certain movements, the visual representations are recorded adequately by self observations - for example, when we move about in the dark in our own house. In other cases, their presence is less evident subjectively although it can be detected by objective methods. One such method is based on the "dilution" of actual and visually perceived locations of a source of sound in the problem where it is required to indicate its position. Using this method, G. Pik, et al. (1969) showed that the subjects localized the sound somewhere between the true and the apparent location of the source, while the degree of deviation to the side of the apparent position varied in different subjects. This example also shows the variable degree of involvement of visual components in the spatial image, which mediates the movement.

The final aspect which we should like to emphasize refers primarily to movements which serve the perception. If we were to feel an object in the absence of vision, then its image would be partially transformed into visual modalities. This is shown by the fact that we can subsequently successfully recognize this object visually without recourse to touch. Consequently, the vision is also involved in the haptic motor process.

In conclusion, it can be said that the problem of the role of vision in movements has both a qualitative and a quantitative aspect. The vision supplies the error signals on the basis of which the current movement corrections are performed; it participates in the programming of movements, either by real visual

stimulation or by image representation; it can finally appear as a "customer" which utilizes the product of movement for purposes of perception. Various effects show that in all the enumerated cases, vision can partially and sometimes entirely transfer its functions to other perception modalities. A principal aid, substitute or competitor of vision is without a doubt the muscular proprioception, although hearing, touch, etc., may replace the latter. In such a manner, in studying the mechanisms of formation, realization, reorganization, etc., of movements, the question of the degree of involvement or of participation of vision in the motor process acquires great importance. However, the thorough investigation of this question is retarded by the absence of objective indicators for the degree of activity of the visual system.

It is exactly in connection with the latter methodological problem that fixated optokinetic nystagmus (FOKN) started to be recently investigated (Gippenreyter, Romanov, 1968, 1970; Romanov, 1971). The results of the investigation led to the assumption that the properties of FOKN were directly related to the degree of internal visual activity, and can be used as its objective indicator.

In the present study, an attempt was made to extend the investigation of FOKN to a new category of problems, hand movements. The purpose of this work was to elucidate whether FOKN / 71 responds to the extent of visual participation in motor acts.

#### METHODS

In all experiments for recording eye movements, A. L. Yarbus' (1965) method was used — a lateral sucker was placed on the anesthetized cornea of the right eye. A light beam was reflected from a small mirror fastened to the sucker onto a

photokimograph chart. By means of this system, eye movements equalling 1 angle min. were recorded per 1 mm of paper. Due to an additional system of beam reflection by means of mirrors situated on an elliptic arc, micromovements of the eyes were recorded even in the presence of relatively large saccadic movements. The FOKN was recorded during binocular fixation of a stationary dot on a moving background formed by vertical black and white stripes, which were moving in horizontal direction with a speed of 14 deg/sec. These stripes were projected on a 180 x 135 cm screen which was situated at a distance of 110 cm from the subject; angular dimensions of the screen were 79 x 63°. The size of each (black and white) stripe was 10 cm, which corresponded to approximately 5°. In all, 9 black and 9 white stripes appeared on the screen at the same time.

Four subjects took part in the experiments; however, due to technical reasons, the recordings of only two subjects could be processed. One of these subjects was a specialist psychologist, and the other had secondary education.

In all the experiments, the subjects performed some kind of movement with the hands without gazing at the hands; as mentioned above, the subjects fixated continuously a dot situated in the center of the screen, which contained the moving stripes.

The experiment consists of two series. In the first series, a simple movement of a single type was used, linear forward and reverse displacements of the hands. The conditions which change the afferentation of this movement were varied. In the second series, more complicated graphic movements were used. The main comparison was made along the line of more or less automated writing movements. We shall dwell on the methodological features of each series. / 72

First series. The main problems were movements of the hands between barriers and movements according to a visual standard. In addition to the main task, two "intermediate" ones were introduced: in one of these, the subject had to repeat movements from his motor memory, while in another, he had to reproduce distances from visual memory. All four problems could be ordered according to the degree of the assumed visual participation: the less "visual" was the task of "movement between barriers" (Condition I), followed by "movement from motor memory" (Condition II)\*, "movement from visual memory" (Condition III), and finally, "movement according to a visual standard" (Condition IV). If the FOKN would indeed react to the extent of visual participation in the movements, then ordered changes of its parameters would be expected according to the suggested increase in the "visual degree" of the described problem.

The details of each of the enumerated conditions were the following. The visual length was represented by means of a couple of dots projected on the screen on both sides of the fixation dot. The distance between the two outermost dots varied from 4 to 12 cm, which corresponded to a range of from 2 to 6°. When the visual length was reproduced from memory, the standard (also a pair of dots) was presented for about 5 sec and was then switched off. The movement from motor memory consisted in that the subject assigned to himself a standard movement, and then attempted to reproduce it accurately. In the movements between barriers, the subject did not have to worry about the amplitude of the movements, as these were determined by mechanical limiters.

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\* Generally speaking, conditions II permitted the inclusion of visual components, since the subject was instructed to relate to the length of the given movement in the coordinates of the environment rather than of his own body.

In all the conditions, the subject was asked to repeat the movements in both directions as long as the experimenter did not signal him to stop. Usually he managed to perform by this time 10 to 20 full cycles of hand movements. In each 3-4 minute experiment, two of the four enumerated conditions were used. Throughout the series, each condition was repeated in at least two of the experiments with each subject.

In all the experiments of this series, the hand movements of the subject were expressed in the movements of a pencil, the end of which was placed in the slit of a horizontal surface. The slit had a maximal length of 30 cm; it was situated opposite the right hand of the subject, and was parallel to its frontal plane. The bottom of the slit was in fact the surface of a rheostat, while the pencil was a contact, the movement of which changed the output voltage. The voltage change was translated into the displacement of a beam, which was focused on the same slit of the photokimograph as the beam coming from the mirror of the sucker. In such a manner, synchronous recording of the eye and hand movements on the same chart was insured.

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Second series. In the second series, a comparison was made between the repeated reproduction of the subject's own signature, and the writing of simple foreign language words in capital letters. It was assumed that the second problem involved a greater visualization of letters, i.e., of movement programming, than the first.

In each experiment of the given series, the subjects used half of the time to reproduce several times their signature, and the other half to write the following known foreign language words in block letters: EIN, ZWEI, DREI or ONE, TWO, THREE. Of course, the order of these assignments was changed in different experiments. The subject was advised to write at his

own natural pace. The writing movements were recorded on a special photokimograph (manograph) by means of a light pencil. This recording was organized in such a manner that it allowed to obtain both a spatial and a time tracing of the graphic movements. The synchronized time marker made markings simultaneously on the hand and eye recordings, which made it possible to compare both recordings subsequently, with an accuracy up to periods of writing separate letters and even of individual elements of letters. In the beginning and often at the end of the experiment, the "background" FOKN was recorded, i.e., the FOKN during the fixation of a stationary dot without any additional motor tasks. At least two and usually four such 3-4 minute tests were performed with each subject.

## RESULTS AND DISCUSSION

First series. The processing of the results of this series consisted, first of all, in calculating the mean values of the main parameters of FOKN:  $t$ ,  $v$  and  $l$  of the slow phases. Evidently, of the named magnitudes, only two were independent variables, while the third was a derivative of the first two. However, we did not know in advance which FOKN parameters would react to the change in the type of movement, and therefore we processed each of these separately.

A preliminary analysis of the results revealed the dynamics of FOKN within the conditions, i.e., within a certain type of movement in the course of its repetition. As mentioned above, in each individual test, the subject performed not one, but a series of movements, in all at least 10 cycles. Therefore we could calculate the averages in the various cycles, related to the beginning and to the end in each series of movements. For this purpose, 1-3 and 8-10 hand cycles were chosen.

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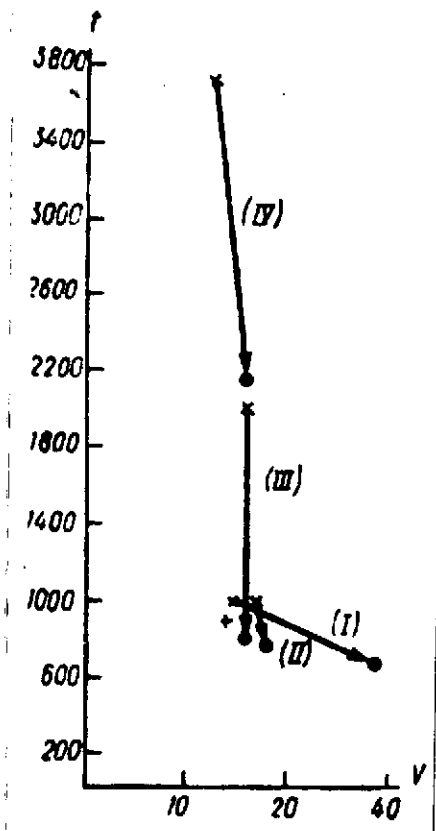


Figure 1. Average values of  $t$  and  $v$  of FOKN in 1-3 and 8-10 cycles of the hand in different conditions of the first series:

I- Movement between barriers;  
 II- Movement from motor memory;  
 III- Movement from visual memory;  
 IV- Movement according to a visual standard (Subject 2)

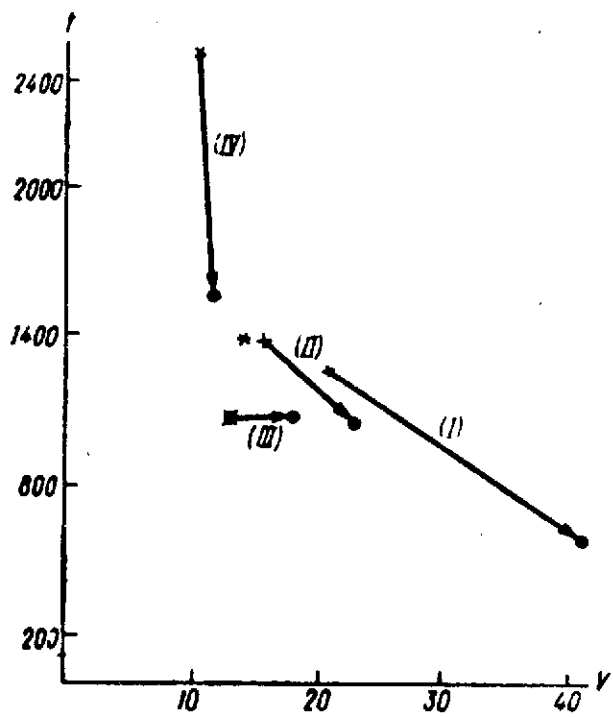


Figure 2. Same as Figure 1 (Subject 1).

Legend to Figure 1 and Figure 2.

X — 1-3 cycles  
 • — 8-10 cycles  
 + — Background FOKN

Of special interest was the comparison between the first and the last hand cycles. It is known that repetition of a movement, regardless of its initial afferentation, is related to the transition of the control of this movement to muscular proprioception. In such a manner, changes of FOKN inside the conditions can be interpreted as its reaction to the dynamics of afferentation of the hand movements.

The results obtained separately for each subject are presented in Figures 1 and 2. The comparison between conditions (in 1-3 cycles) shows significant differences\* in the case of subject 1 between Condition IV and all the other conditions (in Condition IV, the largest  $t$  and the smallest  $V$  were found) and in the case of subject 2, between Conditions IV and III, and between these two and the remaining conditions (the largest  $t$  and the next one in magnitude, respectively). A comparison between the first and the last cycles reveals a significant decrease in  $t$  and an increase in  $V$  in Condition I in subject 1, while in subject 2, there was a significant decrease in  $t$  in all four conditions.

In such a manner, quantitative processing of the FOKN parameters revealed the sensitivity of either  $t$  alone (Subject 2), or of  $t$  in combination with  $[v]$  (Subject 1), in the first place, to a clear involvement or exclusion of vision from the control of movements (Conditions IV and III and compared to I,) and second, to a weakening of the visual control in the process of movement repetition. The nature of the changes in the indicated parameters is in agreement with the earlier tendency to suppression of FOKN in more visual conditions and its surging in less visual conditions (Gippenreyter and Romanov, 1970).

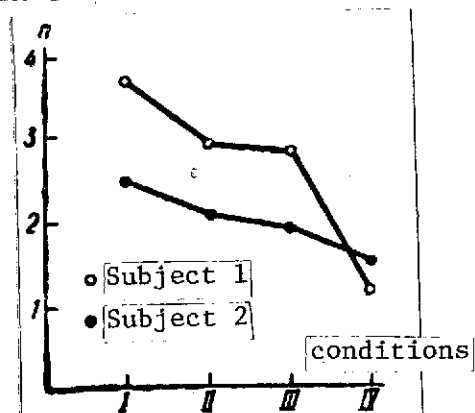


Figure 3. Number of FOKN cycles per one hand cycle in different conditions (1st series)

\* According to the Student Criterion at  $\alpha=0.95$ .

The results of the described series were processed by additional means as well. One of these consisted in calculating the number of FOKN cycles per one cycle of hand movements: as was indicated before, in all the experiments the subject used a free pace of hand movement; in fact

this pace was different in different conditions.

Figure 3 depicts the graphs of the relative frequency of FOKN in different conditions for each subject. Again it can be seen that the visual condition IV is clearly distinguished from the others, i.e., the relative frequency of FOKN is much lower here than in the other conditions, where the differences are either absent or are less marked. The qualitative analysis of the simultaneous recording of hand and eye made it possible to understand the reason for the latter fact. At the same time it revealed a new, remarkable feature of FOKN.

Let us refer to Figure 4, which presents samples of synchronous recording of hand and eye movements in two limiting cases: IV (visual) and I (purely motor). The first recording a shows that the slow phases of FOKN continue as a rule throughout the period of hand movement, and stop by a jump upon its completion, i.e., when the hand reaches one of its extreme positions (on the recording this corresponds to the minima and the maxima of the sinusoid). Contrarily, the jumps on the second recording b are observed occasionally along the sinusoid and often during the period of hand movement.

The described finding was processed quantitatively by calculating the percentage of jumps of the eye during the period of halt (minimum and maximum of the sinusoid) and of hand movements.\* As a result, the following distribution of the percentages was found:

	Halt	Movement
Condition I	50%	50%
Condition IV	80%	20%

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\* The overall length of each period was nearly the same.

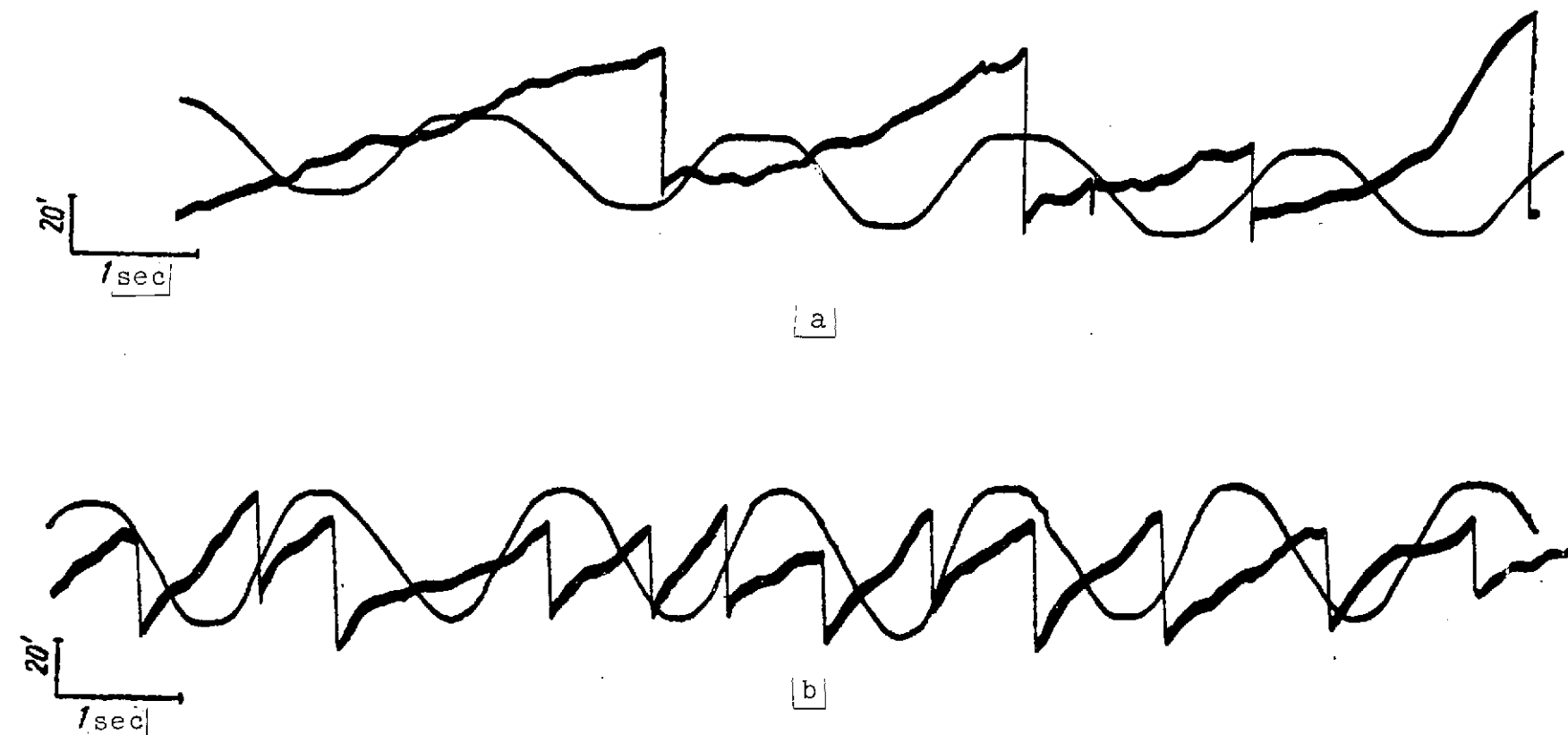


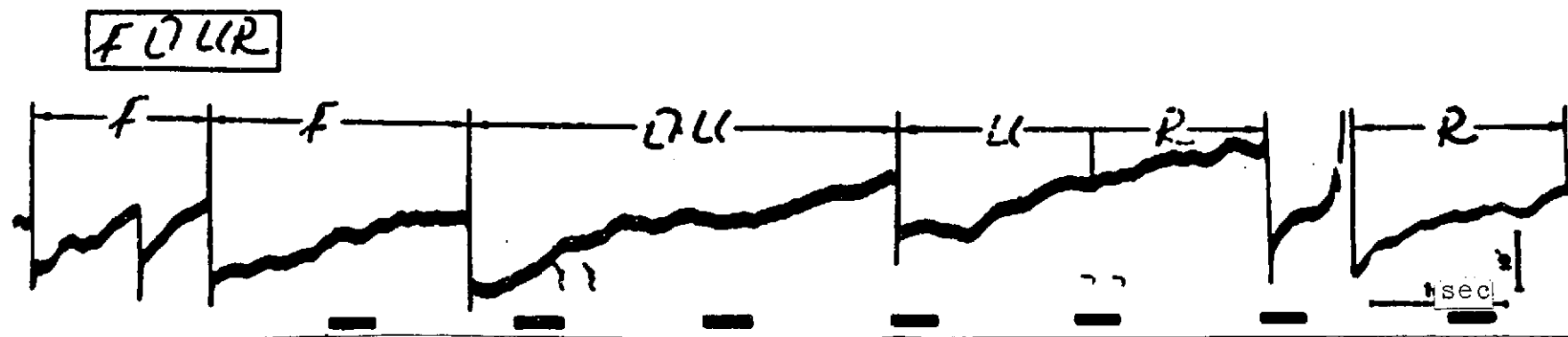
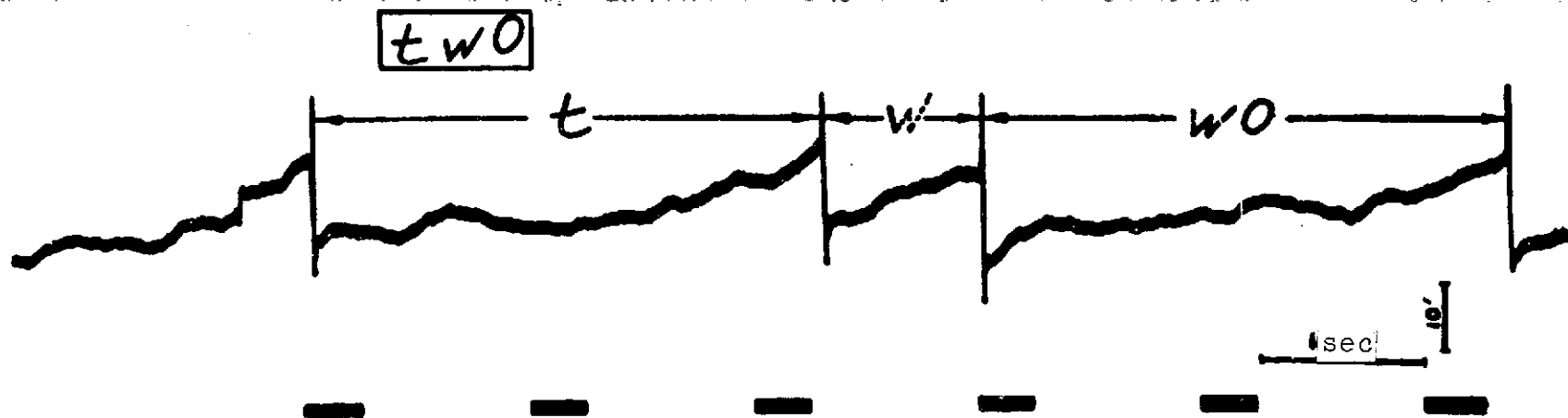
Figure 4. Recordings of the hand movements (sinusoid) and FOKN:  
 a - in movements according to a visual standard (Condition IV);  
 b - in movements between barriers (Condition I).

The following explanation of the described findings suggests itself. In Condition IV, i.e., in the movement according to a visual standard, the eye continuously "follows" the hand in order to measure the amplitude of its movement. The continuity of the visual control is expressed in the continuity of the slow phases of FOKN. Upon completion of the movement or when it appears in a larger "portion" (2-3 half periods of the hand), interruption of the visual control takes place. This is expressed in a rapid phase, a jump in the FOKN. In Condition I, vision does not participate in the organization of the hand movements. Accordingly, the stages of FOKN are not related to the periods of this movement.

The described findings led to a new view on the relation between FOKN and the visually controlled activity. However, before presenting this new view, let us describe the result of the second series.

Second series. As mentioned above, the procedure of recording the graphic movements made it possible subsequently to relate the recordings of these movements to the cycles of FOKN with greater precision. Figures 5-8 present sample parts of FOKN corresponding to the period of writing in block letters of foreign language words (Figures 5-7) and repeated signatures (Figure 8). On each recording in a small box is presented the corresponding word as it was written by the subject; the periods of writing of the individual letters of every word are indicated below.

The first striking finding is that a certain event in the hand corresponds to each jump in the FOKN. As a rule, this is the completion of one and the beginning of another, graphic element, such as words, letters or parts of letters. The opposite of this rule is not true: the end of each letter is not



accompanied by a jump, and this is even more true for the end of each element of a letter. As a result, two neighboring jumps and the drift between them divide up the movement into larger blocks or "units". The magnitude of these units is extremely variable: from a whole word to a part of a letter, or even to halting of the hand before a letter or part of it. In the case of the signature, a clear tendency to an increase in the size of the units is observed: either half of the signature of the whole signature forms such a unit.

With regard to the speed of the slow phases, no definite patterns were observed: in the case of the block letters, it was not less than in the case of the signature. The speed varied sometimes quite markedly within the limits of one drift.

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Interesting additional material was unexpectedly obtained in the experiment with Subject 1. In writing the foreign letters, this subject forgot from time to time how to write a certain letter\*. Figure 7 presents a part of the experiment where this happens twice: in the word "sieben" the subject could suddenly not remember how to write the letters S and N. She reported this at the end of the experiment: this was reflected in the writing of the letters (see Figure 7). Analysis of the time dilution in the writing of the words in conjunction with FOKN shows that FOKN "reacts" in a specific manner to difficult moments during the writing: often short cycles appear with a large speed of the slow phases. Each drift corresponds to a very small fractional element of a letter.

Thus, the result of the second series confirms the finding observed in the first series, i.e., that the phases of FOKN

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\* During the last several years since she finished high school, the subject had had practically no contact with foreign languages.

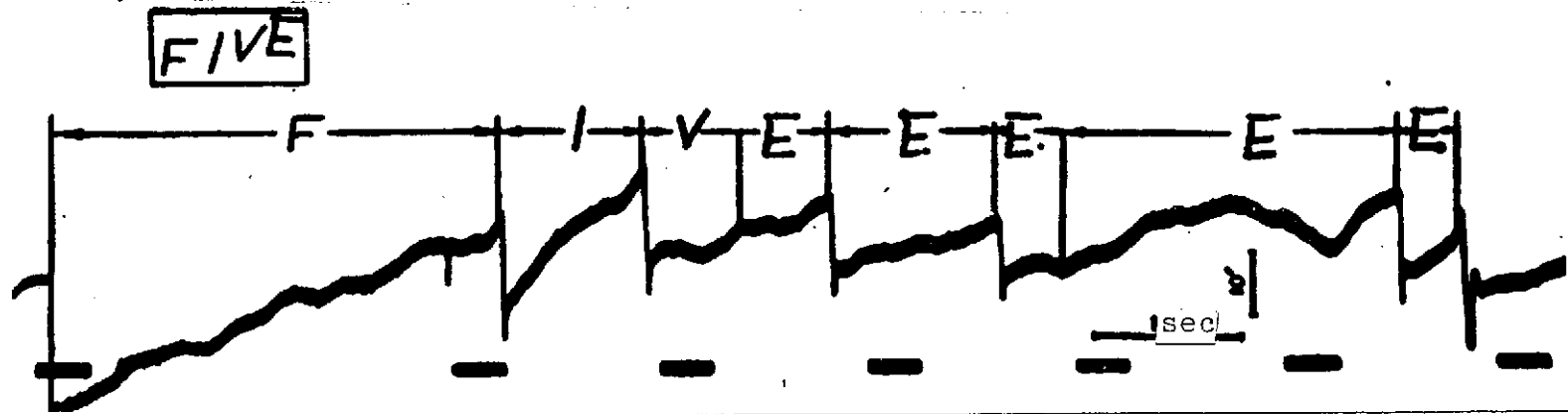


Figure 5. FOKN in writing foreign language words in block letters (Subject 1). Here and further, the discontinuous line above each FOKN cycle indicates those parts of letters which were written during the given cycle. For the sake of clarity, these parts were completed to the full letter by means of dots.

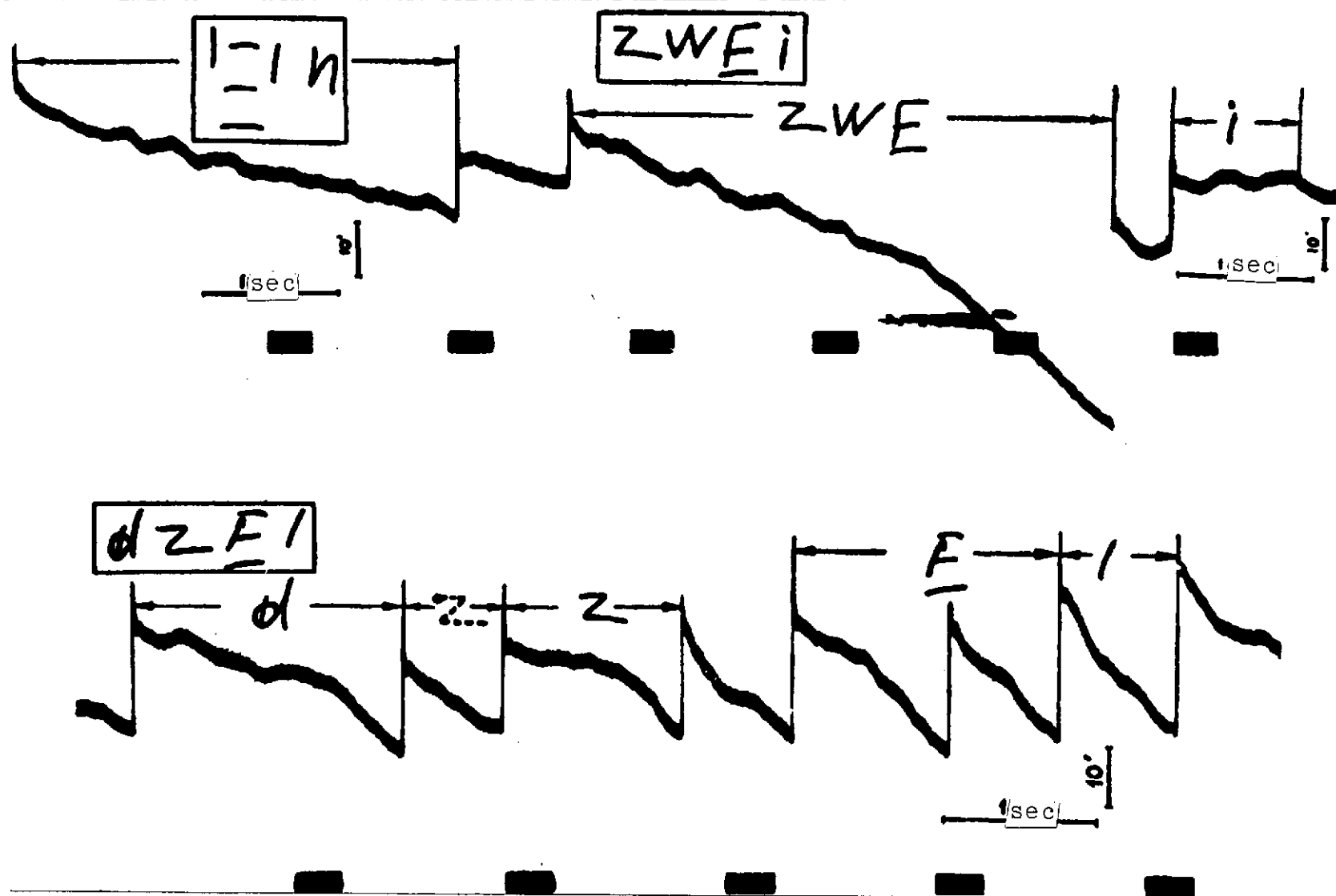


Figure 6. Same as Figure 5 (Subject 2).

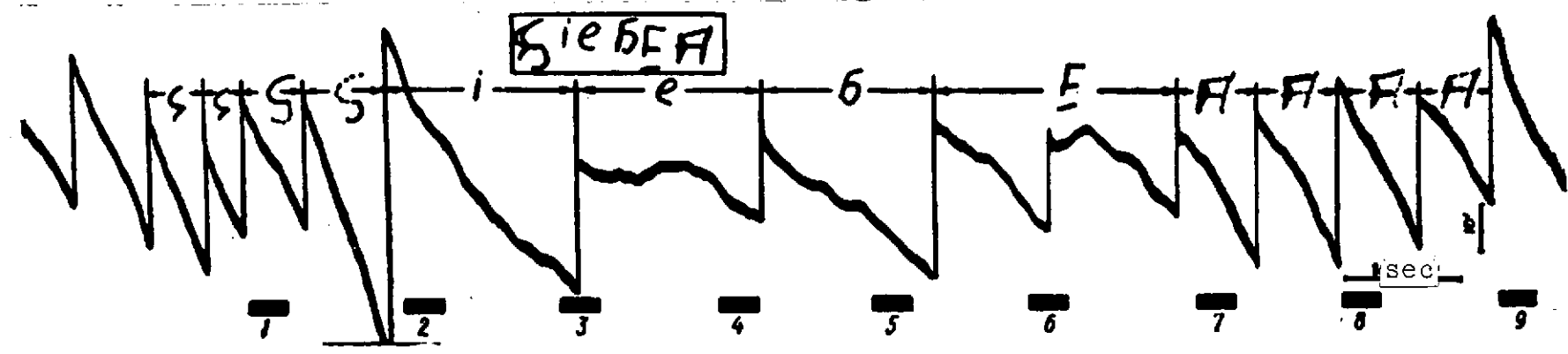


Figure 7. FOKN during the forgetting of block letters (Subject 1).

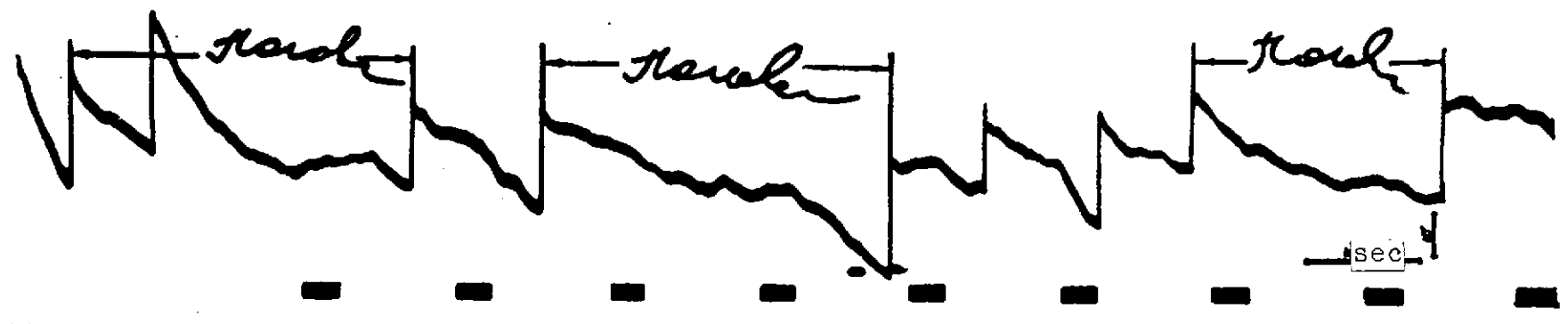


Figure 8. FOKN during the writing of the signature (Subject 1).

indeed distinguish between several units in the movement.  
What are these units?

The data show that these are undoubtedly related to the visual control. Let us note immediately that this concerns the internal visual control, since in all the experiments, the subjects did not gaze at their hands but fixated the dot on the screen.

The continuity of the drift in the signatures can be explained by the fact that the visual afferentation of these movements is not only weakened due to the muscular proprioception, but is also not elaborated. If the eye "follows" the hand, it does so as if it were in integral movement, "attached" to the environment\*; the care about the details of this movement is transferred to muscular proprioception. A different situation is created in the writing of foreign language words. It is quite probable that in our subjects, no coherent motor images of these words were present. They had to plan individual elements of words or of letters in the course of their repetition. The individual cycles in the FOKN reflected the realization of this partial visual programs. In the case of the forgotten letters with Subject 1, whole images of the letters were absent, and the subject reconstituted them from simple elements; correspondingly short frequent cycles were observed in the FOKN.

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Thus, our hypothesis states that the FOKN cycles reflect discrete blocks in the realization of visual programs of movements or units of visual control. Perhaps can we consider them

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\* The subjects reported that in the experiments of the second series, they had to be careful that the hand does not go beyond the limits of the paper chart on which their movements were recorded. In other words, they matched the amplitude of the hand displacement with the width of the paper (14 cm).

at the same time as units of a purposeful activity? This is still a very general assumption, but it opens wide prospects for investigation.

## CONCLUSIONS

In the beginning of this study, we intended, just as before, to evaluate the degree of participation of vision in movements, by averaging the quantitative parameters of FOKN during comparatively long periods of time. Such a "global" approach to FOKN was until now not only justified, but it seemed to be the only possible approach. Nevertheless, we constantly felt that FOKN is potentially a richer method and can be utilized for microanalysis of the process of activity. Nevertheless, the methodological procedure for solving this task was not immediately evident. As a matter of fact, all types of cycle activity which have been utilized until now in our investigations did not allow an objective recording of its immediate course. As a result, we had to limit ourselves to a representation of the structure and dynamics of the activity with the limitation in accuracy imposed by logical analysis of the conditions and the subject's own observations. Motor /83 tasks represent a unique material, inasmuch as they permit objective recording of the continuous course of their solution. In such a manner, the use of FOKN in motor problems opens new possibilities for a continuous comparative analysis of two dynamics, the FOKN and the main activity.

In the present work, it is not only the reaction of the quantitative FOKN parameters to the participation of vision in movements which has been revealed, but an even more important finding: the coincidence of the FOKN cycles with individual "blocks" of movements, which are larger in the case of more automatized movements and smaller in the case of less au-

tomated \ movements. This finding led to the assumption that units of visual control are reflected in the phases of FOKN.

There is hope that further development of this result will assist in using FOKN for the analysis of the vital flow in the purposeful human activity.

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